# Coastal and Hydraulics Laboratory

The big news in FY 97 for the Hydraulics Laboratory and the Coastal Engineering Research Center (CERC) was their reorganization into one research entity, the Coastal and Hydraulics Laboratory. This new laboratory is the world's leading organization for coastal and hydraulics research.

The Hydraulics Laboratory was the original "Waterways Experiment Station" that was established in 1929 and was the principal Corps agency for engineering research and experimentation in hydraulics and hydrodynamics. CERC evolved from the Beach Erosion Board that was formed by Congress in 1930. CERC grew to become the United States' national coastal engineering research laboratory. Together as the Coastal and Hydraulics Laboratory, they will focus on inland and coastal flood control, navigation, dredging, harbor design and improvement, groundwater, sand bypassing, environmental problems associated with inland or coastal waterways, military hydrology, and military operations in the coastal zone.

The new Coastal and Hydraulics Laboratory will focus a wealth of expertise and capability into solving problems associated with inland and coastal waterways. The merger resulted in a more efficient research organization and eliminated 12 positions, including five high-grade positions. The annual savings due to these personnel reductions will exceed $1 million.

**Rapidly Installed Breakwater (RIB) System**. U.S. force projection strategy relies heavily on moving equipment and supplies via sealift. Damaged, inadequate or non-existent port facilities will require Logistics-Over-The-Shore (LOTS) operations where supplies are offloaded to smaller vessels for transport to shore. LOTS exercises have shown that sea state 3 conditions (wave heights of 1 to 1.5 meters) degrade or even shut down LOTS operations. These or even worse sea-state conditions exist much of the time worldwide.

The WES solution for this problem is the RIB System — a V-shaped floating structure consisting of two legs joined at the front and anchored at each end. It creates a sheltered area of relatively calm water inside and behind the structure for LOTS operations and is rapidly deployable and low cost.

*Field deployment of a 1:3-scale version of the RIB System. Notice the calmer water behind the RIB System*

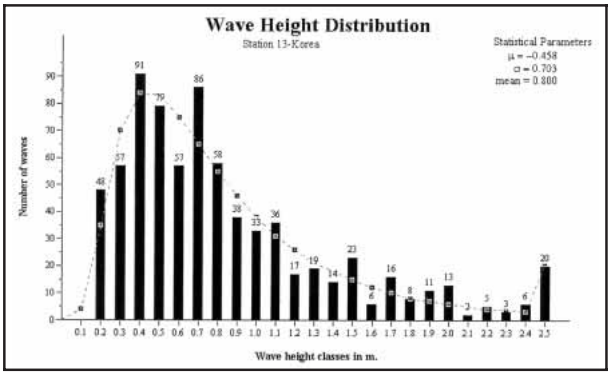
In 1997, WES successfully deployed two 1:3-scale versions of the RIB System in Pensacola Bay, Fla., to study wave suppression and deployability aspects of soft versus hard structures. The "hard" frame RIB was designed and fabricated at WES from a combination of welded-steel structures (radio tower frames) and closed-cell foam flotation. The "soft" RIB structure consisted of two large "water beams" made of a watertight vinyl sock encased by polyester webbing that used sea water to pressurize the RIB legs. Each version's legs were about 61 meters long.

Results showed that each system has potential to significantly improve LOTS operations. Based on the previously successful laboratory tests and these field studies, it is probable that the RIB System will be integrated into the Army's inventory in the future for use in LOTS operations.

**Coastal Integrated Throughput Model.** WES and the Military Traffic Management Command are developing the Coastal Integrated Throughput Model (CITM). As an operational analysis tool, CITM will allow commanders to evaluate various Joint Logistics-Over-The-Shore (JLOTS) alternatives such as site selection and asset assignment. In a real-time operational mode, CITM will allow commanders to rapidly assess impacts of adverse weather, damaged or lost assets, and quickly choose the best available course of action, such as diverting or relocating assets. Scheduled for completion in FY 99, the first version of CITM was developed and successfully evaluated in FY 97.

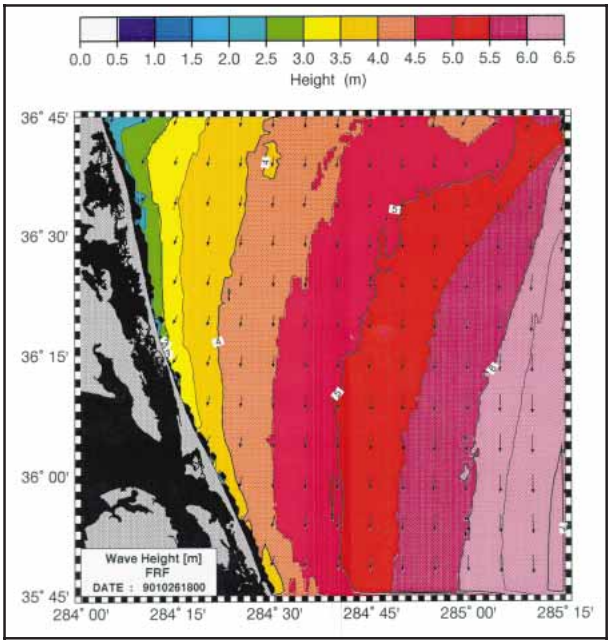
**Global Sea State Climatology for Logistics-Over-The-Shore (LOTS).** Optimum site selection for a successful LOTS operation is influenced by sea state, water levels, and currents. Since sea state is particularly important, WES is developing a capability to rapidly generate global sea-state climatology for use in LOTS operations using numerical models.

Following model execution, seasonal wave statistics are automatically computed and include wave height and period distributions, joint wave height and period distributions, and duration statistics. A demonstration wave hindcast was recently performed for the sea around Korea, which has great variability in wave climatology (deep and shallow waters, distinct winter and summer wind and wave regimes, typhoons, and tide ranges up to 6 meters).




*Wave height distribution for a location on the Korean coast*

**Coordinated Army/Navy Spectral Wave Modeling Initiatives.** Three efforts were initiated to significantly improve spectral wave modeling in the Department of Defense. The first is a collaborative Army/Navy effort in shoaling waves where the source/sink terms will be measured in a massive field experiment in 1999. The 3GWAM model was modified so that wave simulations are performed on scales never before required (resolutions less than 1 kilometer).




*Wave heights predicted at the CHL Field Research Facility with spectral wave models*

The second effort is the direct application of the 3GWAM model in real-time wave forecasts. Navy and Army operations in the littoral zone rely on high-resolution wave forecasting and timely transmittal of that information to the field. The Common HPC Software Support Initiative is providing the means to transition 3GWAM from vector systems to scalable computing environments. In only 18 months, computational run time has been decreased by a factor of 2 to 4 using platform independent procedures.

The third effort is a continued collaborative effort between WES and the Naval Oceanographic Office (NAVOCEANO), one of the two Navy operational forecasting centers. A Graphics User Interface was developed to greatly simplify the initiation of a rapid response Spectral WAve Prediction System (QSWAPS). In many instances, QSWAPS can now be set up and tested to meet the needs of the warfighter in a day.

**ALBTCX (Airborne Lidar Bathymetry Technical Center of Expertise).** In FY 97, WES and the Corps of Engineers' Mobile District began joint operation of a Corps-wide center, ALBTCX, in Mobile, Ala., to operate the SHOALS (Scanning Hydrographic Operational Airborne Lidar Survey) system. ALBTCX also provides a variety of related SHOALS products and services, including bottom-type characterization, coastal structure condition assessments, and submerged vegetation mapping.

Operating from a helicopter, SHOALS fires a pulsed laser to generate a uniform 4-by-4 meter sounding grid, covering 8 square kilometers per hour, that produces dense, accurate, and rapid surveys of navigation channels, nearshore bottoms, and adjacent shore areas. A self-contained data processing trailer allows on-site analysis and product generation in the field. Since 1994, SHOALS has surveyed more than 200 projects, including an 800-square-kilometer survey off the coast of Mexico, and has conducted survey work for the U.S. Navy, the National Ocean Service, and the Corps of Engineers.

*Longshore sediment transport facility*

**Longshore Sediment Transport Facility (LSTF)**. The LSTF's water recirculation system, consisting of 20 individually controlled and metered pumps and associated piping, was completed this year. The 3-D, movable-bed LSTF will simulate on a large scale the nearshore physical processes and the resultant movement of sediment that causes shoaling in navigable coastal waterways. It will improve prediction of the rates and patterns of longshore sediment movement, optimizing management of navigation projects to achieve the best balance between navigation needs and effects on adjacent shorelines.


*SHOALS airborne survey system and data processing trailer*

The LSTF basin is 1.4 meters deep, 50 meters long, and 30 meters wide. It will use a closed-loop system to replicate circulation and sediment transport rates equal to 84,000 cubic meters per year. Its four unidirectional spectral wave generators can produce wave heights of 0.5 meters. An automated programmable rail-mounted instrumentation bridge spans the active beach region and allows measurements at cross-shore transects anywhere along the beach.

**Automated Coastal Engineering System (ACES).** The PC version of ACES (PC-ACES) allows application of a broad selection of coastal engineering technologies within the limits of personal computer capabilities. There are over 1000 users of PC-ACES, including the Corps of Engineers, domestic and foreign government agencies, academia, and the private sector.

The ACES 2.0 system handles more complex and comprehensive tasks. This system focuses on integration of commonly used data bases, development of graphical user interfaces to expedite grid generation and data set building, and visualization methods to augment data analysis and interpretation. Regional Wave Information Study wave data bases and National Ocean Service bathymetry data bases are incorporated, along with direct access to them for input data preparation and automated grid generation. Capabilities for animating beach profile evolution and shoreline change provide the user with useful ways to visualize the time-dependent behavior of simulations. The workstation version of ACES 2.0 was completed this year and work began on porting this version to a Windows NT environment.

**SandyDuck Experiment at the Field Research Facility (FRF).** The FRF, located in Duck, N.C., is the worldwide center for cooperative field experiments in coastal and nearshore processes. The FRF's barrier island site gives more than 900 meters of ocean or sound frontage, and a 560-meter-long concrete and steel pier extends through the surf zone, providing a platform for measurements during storm events. The FRF staff has great coastal research expertise and unique equipment, such as the Coastal Research Amphibious Buggy (CRAB) and the Sensor Insertion System (SIS). The SIS is a rail-mounted crane on the pier that allows rapid, precise deployment and retrieval of instrument packages during storm conditions, in waves up to 5 meters.

*The CRAB pulls an instrumented sled into the ocean during the SandyDuck experiment*

In 1997, a major nearshore processes experiment called SandyDuck was initiated at the FRF. Sponsored jointly by the Office of Naval Research, the U.S. Geological Survey, and the Corps of Engineers, SandyDuck is a collaborative effort among more than 100 researchers from 18 universities, six federal agencies, two private companies, and three foreign countries. More than 400 instruments were installed at the FRF. Measurements began in late September and continued through early November 1997. The resulting data will be shared and analyzed to improve fundamental knowledge and test theories and hypotheses relating to sediment transport in the nearshore zone.

**CORE-LOC: New Concrete Armor Unit.** WES researchers developed a revolutionary new concrete armor unit called the CORE-LOC. They received a U.S. patent and have applied for patents worldwide. WES has licensed the CORE-LOC technology to several international engineering firms and will complete negotiating all licenses in FY 98.

CORE-LOC was developed to armor navigation structures in severe wave environments. Ranging in size from a few tons to 70 tons, they are versatile enough to use on most other coastal structures. CORE-LOC has outstanding interlocking features and is much more stable and stronger structurally and requires significantly less material than other existing armor units.

In 1997, 15-ton CORE-LOCs were used to armor a breakwater and peninsula at St. Francis Bay in South Africa (the CORE-LOC armor layers survived four design level storms during construction); jetties at Manasquan, N.J., were repaired with 19-ton CORE-LOCs; and CORE-LOC armor layers were under construction in the Cape Verde Islands and Oman.

**Physical Model Experiment Put to Test in Cape Verde Islands.** The port of Vale de Cavaleiros is in the island Republic of Cape Verde, off the African coast. In the 1960s a breakwater was constructed with an armor layer

*St. Francis Bay CORE-LOC breakwater construction*

*One-thousandth CORE-LOC used in the Cape Verde Island breakwater*

of 6.25-ton tetrapods fronting a recurved seawall. Damage began soon after the breakwater's completion due to wave conditions at the site.

A plan to rehabilitate the breakwater was modeled at WES in 1996. The plan included extending the breakwater length, placing all salvageable tetrapods at the root end of the breakwater, and placing 12-ton CORE-LOC armor units on the remainder of the structure. Construction of the breakwater began in mid-1997 and is going well. Up to 60 CORE-LOC units per day are being placed on the structure. The structure has seen several large storms during construction, and the completed CORE-LOC sections have been completely stable.

**Paraguay-Parana Rivers, Hidrovia Project.** The South American Paraguay-Parana Rivers Hidrovia Project covers 3,400 navigable river kilometers and involves the countries of Argentina, Brazil, Bolivia, Paraguay and Uruguay. While the river supports 2 meter navigable depths for most of the year, during low water, navigation depths and other problems restrict commerce. The countries have formed the International Commission on the Hidrovia to serve as the project advocate to facilitate commerce improvements through studies and construction.

Navigation improvements to the river must be evaluated in concert with the project costs and social and environmental impacts. Also, development banks require that such water resources projects be sustainable. Commercial firms completed feasibility and environmental impact studies on the Hidrovia Project in early 1997, concluding that the project would have

*Parana River, Paraguay*

an insignificant impact on the environment and would cost about $100 million. An international panel of experts reviewed the studies and reported that these findings were not substantiated by analysis or data.

The U.S. State Department organized a trip for the President of Paraguay to view U.S. projects similar to the Hidrovia and to visit WES. A team of WES engineers were then requested to travel to Paraguay to provide assistance on the Hidrovia. The Paraguayan President requested the WES team review the Hidrovia report and accompany the country's representatives to the 25th meeting of the Hidrovia. WES conducted the review and made a presentation to the Hidrovia meeting. The WES team concluded that the present project did not reflect sufficient studies and analyses to substantiate sustainability.

At the request of Paraguay, President Clinton endorsed the use of WES to provide technical assistance. Paraguay has requested that WES prepare a proposal for efforts to accomplish sufficient engineering and environmental studies for decision making. It is anticipated that the International Commission on the Hidrovia will request similar WES technical assistance. WES plans to host a conference on Sustainable Water Resource Projects in Latin America in March 1998, in conjunction with the Hidrovia.

**Upper Mississippi River Study (UMRS).** The comprehensive UMRS is evaluating the effects of increased commercial traffic (fostered by increasing current lock sizes) on the Upper Mississippi River-Illinois Waterway. The UMRS is developing a system of computational tools and integration techniques that can assess the impacts on the aquatic ecosystem from increased navigation traffic to help aid in designing required mitigation measures.

WES is involved in numerous tasks associated with the UMRS, including (1) determining navigation effects of towboats, (2) a hydraulic classification scheme, (3) developing a refined two-dimensional (2-D) model to predict the detailed impacts of increased tow traffic, (4) sediment transport modeling to quantify tow induced resuspension and bank effects, (5) model integration to provide linkage between the various modeling efforts, and (6) development of a comprehensive system model to determine the systemic impacts of increased navigation traffic.

Towboat navigation effects were studied using a 1:25-scale model in a 20-meter-wide by 120- meter-long flume. The model helped to determine the magnitude and duration of velocity, shear stress, and water level changes due to tow passage. This study also provided input and verification parameters for 2-D numerical model work.

Hydraulic classification of the aquatic areas provides a methodology to augment evaluation of potential environmental impacts from increased navigation traffic. The classification

*Flume studies of towboat navigation effects*

will be used to extrapolate results obtained from detailed evaluations on specific reaches to the remainder of the system for impact assessment.

The 2-D hydrodynamic modeling effort extended 2-D hydrodynamic modeling capabilities with verification against field sites and the results of the physical forces modeling. The modeling tool is a significant extension of the existing HIVEL2D model currently in limited use in the physical forces study. The model output, in conjunction with the physical forces modeling effort and the sediment transport analysis, will help assess the ranges of physical modifications to the flow field from increased navigation.

UMRS sediment transport modeling is evaluating tow induced sedimentation potential in side channel and backwater areas. The RMA-10 sediment transport model is the backbone of the sediment study. Modifications include development of source terms for erosion and resuspension from tow movement and propellers, development of a near-shore sediment resuspension source term, and determination of the short- and long-term extent of sediment movement.

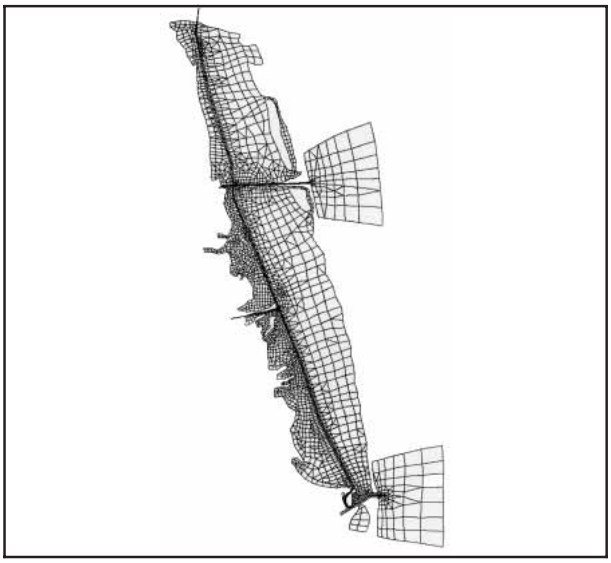
Model integration and the UMRS system model will be accomplished in FY 98. Through integration, the UMRS will be able to efficiently implement, use, and post-process data from both the systems and refined modules. This will also provide computational links to ecological modules developed in complementary research efforts.

**Hydrodynamic and Sedimentation Field Data Collection — Gulfport, Miss.** In a Cooperative R&D Development Agreement with Walk Haydel and Associates, WES conducted a major field-data collection effort to establish baseline conditions for the gross magnitudes and directions of sediment and water movements to support a proposed improvement project for the port of Gulfport.

Reconnaissance level investigations were made to obtain historical data and to perform a field data collection of existing bathymetry, circulation, tides, and sedimentation in the port's anchorage basin and entrance channel. The data included velocity magnitude and flow direction, tide levels, suspended sediment concentrations, and bottom sediment samples. Vertical profiles of the velocity magnitudes, flow direction, and back-scatter intensity for each data collection transect were obtained using a vessel-mounted 1,200 kHz Broad Band Acoustic Doppler Current Profiler.

A fine-grained, 1-meter-thick layer of fluid-mud was identified from the separation of the bathymetric survey records of the two frequencies of depth transducers. Since there is little or no significant flushing in the port area, it acts as a holding area for the fluid mud. The sediment pattern determined from a sample analysis, plus velocity transects, suggests that the most likely cause of the harbor sediment transport is an eddy created from the tidal currents across the mouth of the port and the asymmetrical pattern of the piers (the west pier is longer than the east pier).

**Laguna Madre Estuary Model.** WES is developing a comprehensive numerical model of the Laguna Madre Estuary, which extends from Corpus Christi to Port Isabel on the Texas-Mexico border. Model sensitivity tests are in progress and include 3-D modeling over deeper sections of the estuary, including the Intracoastal Waterway and connecting navigation routes.



*Finite element mesh constructed for lower Laguna Madre*

Model development is in cooperation with the Corps' Galveston District, who want to define sediment dispersion from dredged material placement sites. This work will develop, verify, and apply numerical models to predict the response of the system to disposed dredged material. A secondary objective is to estimate light attenuation parameters from suspended sediment concentrations and floc size factors. Tidal and wind-driven currents will be calculated and combined with wind-wave shear stresses to help determine sediment erosion, deposition, and transport. Scenarios with and without dredged material placement will be calculated.

**Geoacoustic Study and Beach-Fill Borrow Area Assessment of the Florida Coast.** The Corps' Jacksonville District is preparing a feasibility report on shore protection solutions for the Atlantic coast of St. Johns County, Fla. Since beach-fill material is needed due to erosion problems, a borrow area with suitable sediment must be identified.

To help identify potential sites, WES conducted a study to quantify the bottom and subbottom sediments in terms of in situ density, mean grain size, and soil type. A rapid geophysical technique capable of differentiating sediment type and densities was used. Developed by WES through the Dredging Research Program, this high-resolution seismic reflection profiling technique quantitatively assesses the characteristics of bottom and subbottom marine sediments.

A comprehensive subsurface exploration program was accomplished for potential beach-fill borrow areas. An initial assessment was made based on grain size analysis of core and grab sample data in relationship to the native beach. The acoustic data and physical sediment data were combined to characterize the lateral and vertical extents of sediments in the area. Based on this characterization, specific sites were identified for further evaluations.

**Military Hydrology Support for Bosnia Operations.** For the second year, WES provided military hydrology and general civil engineering support to U.S. forces in Bosnia for multinational peacekeeping operations. While the completion of permanent bridging eased the load on the tactical float bridging used in 1996, these assets were still deployed during troop rotations and training exercises. WES continued to provide 10-day forecasts of the Sava River stages at Zupanja and Slovonski Brod. The accuracy of these forecasts continued, with forecasted stages within 4-5 centimeters of the actual stages for the 24 hour forecast. River stages, civil engineering, and meteorological reports were sent via E-mail worldwide. The Internet was also used extensively to disseminate results in graphic and written form.

A NATO report recognized that of the 16 NATO members, only the U.S. forces could forecast river stages in support of military operations. The report recognized that through the use of U.S. Army Corps of Engineers' expertise and software packages, led by WES, the U.S. forces possessed a unique capability. On-going research efforts will provide even more rapid and accurate responses to support the U.S. Army's worldwide missions. The WES Sava River web site (http://chl.wes.army.mil/research/projects/sava/) offers additional information.

**Modeling System Suite of Software Packages.** WES, in conjunction with Brigham Young University and other cooperative partners, has developed three separate modeling systems that address all aspects of water movement. These are the Surface Water Modeling System (SMS), the Watershed Modeling System (WMS), and the Groundwater Modeling System (GMS). These systems provide powerful pre- and post-processing support, allowing rapid model construction, editing, and evaluation of results for numerous hydraulics and hydrology codes.

The SMS supports numerous multi-dimensional hydrodynamic codes for analysis of ocean, estuary and riverine environments and has over 570 government users. Version 5.0, released in 1997, provided the conceptual modeling approach capability. This allows users to rapidly construct a conceptual model on top of a map or photographic representation of the study area. The SMS allows generation and viewing of video file animations representing

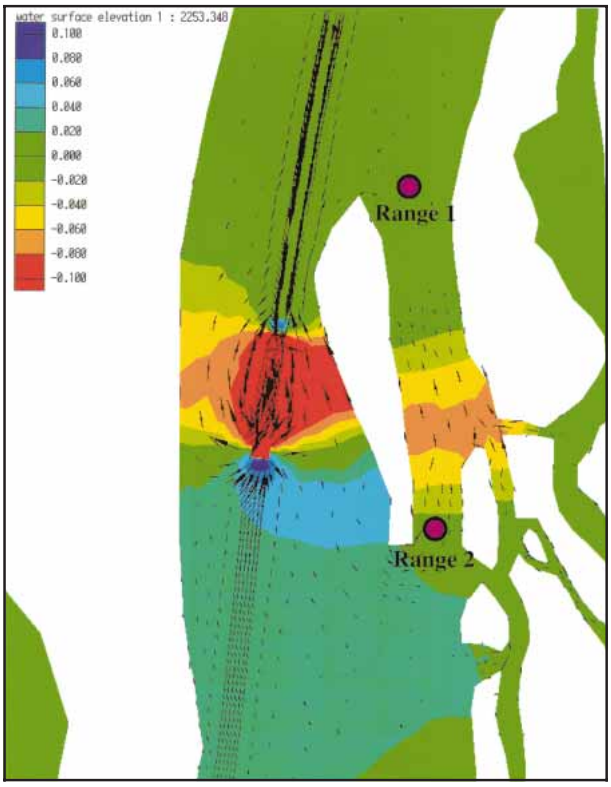
time-varying results. Through GIS/CADD links, the results may be exchanged with the WMS and GMS or other GIS platforms.

The WMS supports various types of lumped parameter and distributed parameter hydrology codes capable of addressing a broad range of problems. The WMS is an integral part of the WES forecasting effort for the Sava River in Bosnia. Version 5.0 was released in 1997 with enhanced GIS/CADD links and support for the continuous simulation version of the 2-D hydrology code, CASC2D.

GMS development, led by WES, involved 15 government research organizations and 20 universities. With over 525 federal users, GMS supports groundwater codes capable of evaluating the movement of contaminated groundwater and rapidly developing and evaluating remedial action scenarios. A powerful geostatistical library is integral to the system, along with GIS/CADD links and animation tools. Recently released Version 2.0 allows modeling complex chemical reactions in groundwater as well as the conceptual modeling approach.

These modeling systems represent a quantum leap forward in productivity and allow routine application of software previously too complex for all but the most rigorous applications. Response time to military tactical hydrology and environmental security concerns has been radically decreased. Continuing development of these systems will enhance both military and civil works capabilities. The web site (http://chl.wes.army.mil/software/) provides additional details.

**Hydrodynamic Model of Vessel-Generated Currents.** Vessels operating in inland waterways generate complex physical forces in the form of waves and currents that are important in both engineering and biological regimes. As part of the Upper Mississippi River-Illinois Waterway System Navigation Study, WES extended the numerical model HIVEL2D to include a moving pressure field that represents a vessel's displacement. Movement of the pressure field is spatially varied in time to represent a vessel navigating along a channel. The hydrodynamics are described using 2-D shallow water equations, which are modified to account for the effects of the imposed pressure field.



*Hydrodynamic model representation of vessel-generated currents*

Existing methods for estimating vessel-induced forces are generally based on 1-D analytical solutions with empirical adjustments. These methods do not provide the time history, duration, or distribution of the currents and waves produced by a moving vessel in geometrically complex natural riverine channels. The new extended HIVEL2D model provides a method of determining spatial and temporal variations in the waves and currents generated by vessels.

**Fisheries Engineering Program.** Hydropower dams in the Pacific Northwest have impacted the numbers of juvenile salmon migrating to the ocean. Various numerical and physical model investigations and field studies are being conducted to re-establish fish runs without losing use of the economically important Columbia-Snake River System.

Over 30 separate studies are under way on fish guidance efficiency systems, surface collectors, outfall citing locations, spillway and powerhouse operations, water quality, and powerhouse turbines. These complex issues are being addressed by engineers and scientists from WES, National Marine Fisheries Service, state fish and wildlife agencies, Bonneville Power Administration, universities, and private consultants.

**Lower Granite Lock and Dam.** Lower Granite Lock and Dam is one of a series of Corps hydroelectric and navigable dams on the Columbia-Snake River system. Located on the Snake River in southeastern Washington, the project consists of a six unit powerhouse, an eight bay gated spillway, and a navigation lock.

In 1996 a surface bypass collector was installed on the powerhouse face to collect and transport juvenile salmon safely across the dam. Field data of fish movement in the vicinity of the project and through the dam were collected during the spring juvenile migrations in 1996 and 1997. A 1:40-scale physical model, reproducing approximately 1,000 meters of the project's forebay, was constructed to document the hydraulic relationships between the surface bypass collector's design, the power house intakes, and the spillway bays. These data, used in conjunction with the prototype field data, will help evaluate the effectiveness of the collector and develop relationships between hydraulic conditions and fish usage of the collector.

A behavioral guidance structure is proposed for installation prior to the 1998 spring migration to aid in guiding the juveniles to the surface bypass collector. It will be 335 meters long and about 24 meters tall. Visual observations of flow conditions, velocity measurements, and differential head measurements obtained from the physical model were used to design the behavioral guidance structure with respect to hydraulic conditions and structural stability.

**Columbia River Ship Simulator Study.** WES completed a ship simulator study for the Columbia River Navigation Project (Washington/Oregon). The conditions in the existing channel make two-way traffic difficult. The Corps' Portland District designed three major modifications for WES to study: a 30.5-meter widening, a 61-meter widening, and a shifted-channel alignment.

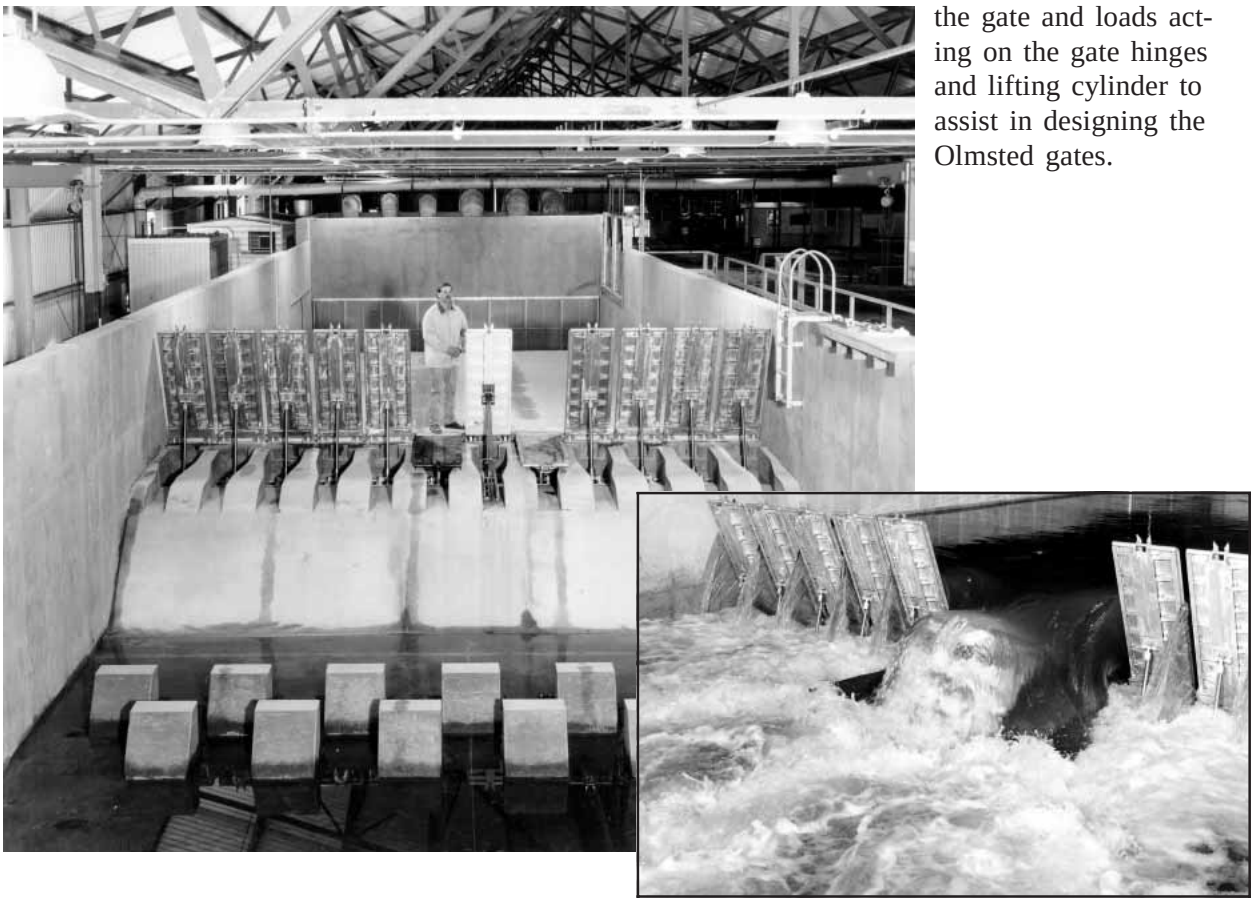
*A Columbia River vessel pilot makes a run on the Ship Simulator to evaluate modifications for the navigation project*

River pilots from the area participated in the simulation study at WES. Two-way daytime and nighttime meeting and passing situations were run. Vessels comparable to existing tankers, container ships, and dry bulk carriers were used for all of the runs. Environmental forces acting upon the ship included river current, tidal forces, bank forces, wind, and ship-to-ship interaction (as the vessels passed each other).

**Olmsted Locks and Dam.** Olmsted Locks and Dam is being constructed on the Ohio River approximately 25 miles downstream from Paducah, Ky., to replace two obsolete dams. Barge traffic moving between the Mississippi River system and the Ohio, Tennessee, and Cumberland rivers must pass through this stretch of river. More cargo tonnage passes this point than any other place in the inland navigation system.

The structure will consist of two 33.5-by-366-meter navigation locks, a section of tainter gates for pool regulation, a navigable pass section (controlled by wicket gates), and a fixed weir. The project has several unusual features, including location in the New Madrid earthquake zone and since it is located near the Mississippi River junction, water levels at Olmsted will be affected by stages of the Mississippi River.

A 1:25-scale model showed oscillating forces were applied to the gates, indicating a potential for structural damage. A 1:5-scale section model was constructed to closely investigate the hydrodynamic forces acting on the navigation pass wicket gates. One of the wicket gates reproduces the elastic properties of the prototype gate and is fully instrumented to investigate gate vibrational tendencies and to determine hydraulic loads on the gates and lifting mechanisms. Experiments were conducted to measure pressures on the gate and loads acting on the gate hinges and lifting cylinder to assist in designing the Olmsted gates.



*The Olmsted 1:5-scale model was used to study the hydrodynamic forces on the navigation pass gates*


*One of the five LACDA models at WES. This 1:55-scale model shows the area of the confluence of the Los Angeles-Rio Hondo Rivers*

**Los Angeles County Drainage Area.** The Los Angeles County Drainage Area (LACDA) study is examining the increased runoff characteristics of the urbanized drainage basins for the Rio Hondo and Los Angeles Rivers and the less than 100-year level of protection. Increased runoff has raised the peak discharge by approximately 20 percent.

Models were constructed at 1:50- and 1:55-scales to determine the flow conditions in the existing channels and to develop modifications to pass the higher flows. Five models, ranging from 33.5 to 192 meters in length, were constructed to cover most of the project reach. WES studies have resulted in significant changes to the proposed project and have reduced the construction costs by close to 50 percent (approximately $260 million).

The original feasibility study called for raising 27 existing bridges to pass the higher flows. Results from WES physical model experiments indicate that 21 of these bridges will not require raising. This can be achieved by either modifying the existing bridge designs (extending the existing piers upstream) or allowing flow to impact the existing bridges (if bridges can survive the flow impact and the resulting flow conditions do not threaten channel integrity).

Although a complete design has not been finalized, modifications developed at WES for several bridges have been constructed in the downstream portion of the project. Channel modifications to contain the additional flow will include constructing parapet walls on top of the levee and raising the levee in some locations.

**MAC3D Numerical Model.** MAC3D is a 3-D numerical model for buoyant flow in reservoirs and water bodies where vertical acceleration cannot be neglected. Extended to account for dissolved-oxygen transport and deposition by bubble diffusers, the model can predict flow and aeration performance, or it can extrapolate experimental data from small (laboratory) scale up to full (reservoir) scale.

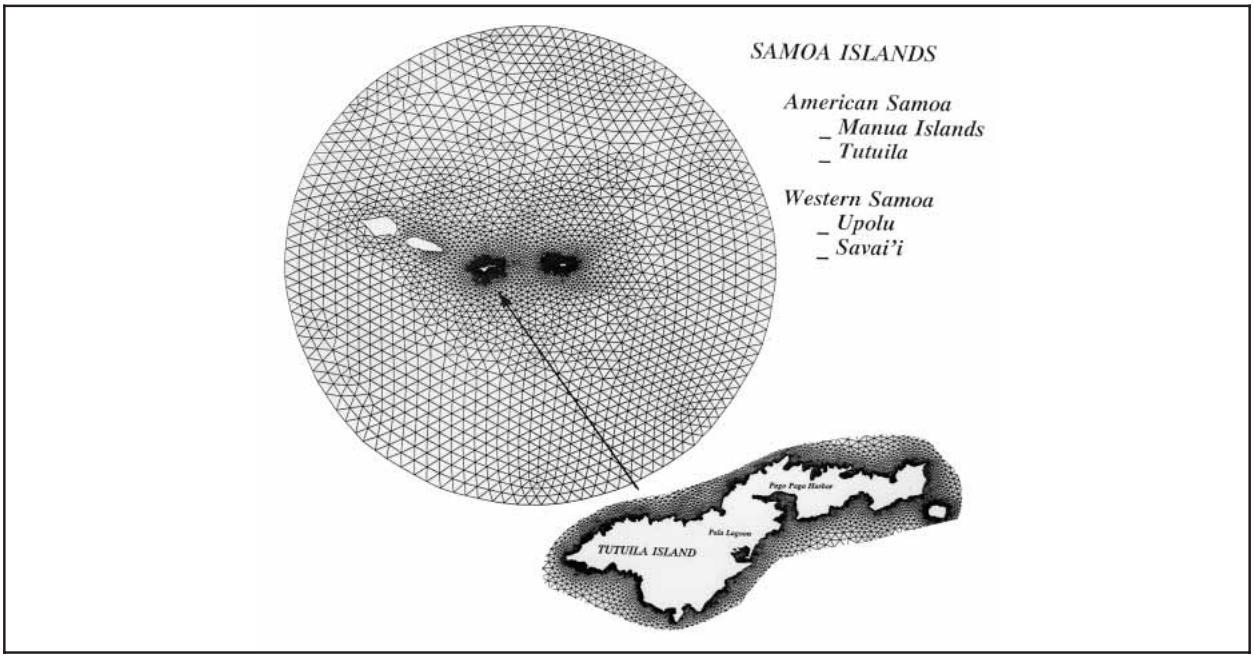
MAC3D is being used to study the effectiveness of candidate aeration systems for McCook Reservoir, a proposed storage-and-treatment facility for sewage and runoff under design by the Corps' Chicago District. This research will help determine whether proposed aeration system designs can keep McCook Reservoir aerobic at all times.

Though initially intended for reservoir applications, MAC3D has also been used successfully to make flow predictions for hydraulic structures and subcritical open channels. A streamlined version of the MAC3D, called PAR3D, is under development for use on computers with multiple (parallel) processors. The PAR3D code will ultimately become part of a larger software package for free-surface flow simulation using hybrid (structured/unstructured) grids.

**Storm Surge Frequency Analysis for American Samoa.** Hurricane Val's landfall in American Samoa in 1991 emphasized the need for more accurate stage-frequency relationships. Frequency relationships were modeled on idealized storm events using a low resolution computational grid, which often results in an over-estimation of low-frequency surge elevations.

Advances in frequency analysis and storm surge hydrodynamics at WES were used to develop a generalized approach to compute storm surge frequency relationships. The full range of probable storm intensities at a given location are modeled using a Planetary Boundary Layer tropical storm model to generate wind and pressure fields. These data are input to the hydrodynamic model ADCIRC (ADvanced CIRCulation) to generate a database of maximum surge elevations at a variety of locations.

The accuracy and ease of implementation of the approach has been demonstrated on a variety of Corps projects and has been adopted by the Corps for use in developing coastal design criteria. The application for Samoa was sponsored by the Federal Emergency Management Agency.




*Computational grid for Samoa*

**Zoned Bioengineering Streambank Stabilization.** Riprap revetment is a classical solution to bank stability problems. However, riprap availability or environmental concerns associated with traditional bank stabilization and river training projects fostered development of bioengineering or "soft armoring" techniques. These techniques depend on vegetation and/or manufactured geotextiles to strengthen the soil, increase roughness to reduce near bank velocity, and induce sediment deposition. Bioengineering approaches offer habitat enhancement, improved aesthetics, and sometimes cost reduction.

In some watersheds, a zoned bank stability approach would benefit both economic and environmental concerns. Low cost bioengineering methods are effective on the upper bank because forces are less intense and less frequent while structural techniques are generally required on the lower bank because frequency and inundation duration are greatest, creating forces that are too large for bioengineering techniques alone. The Riprap Test Facility is being used to determine the base data necessary to develop a design approach for a zoned concept.

**New Channel Protection Products.** Alternative materials and designs to protect flood control channel banklines from scour are being developed. Field experimentation results were used to develop design criteria for a new nonstandard design, cellular concrete mats. In FY 97, laboratory investigations of the cellular concrete mats were conducted, and a standard test protocol based on the limiting velocity was drafted.

During development of the test protocol a generic block was designed and patented. This generic block creates void space to support vegetation (turf grasses and brushy vegetation). It can be applied to the entire bank or to the toe zone only. The block was tested using the protocol and remained stable for velocities of 5.5 meters per second. The block's unique round shape and its key and slot connection design gives the system stability and flexibility. The block can be fabricated as a cabled system, allowing for construction in the wet.

**Innovative Design and Construction Techniques for Navigation Systems.** New navigation locks and dams are needed at many Corps projects to meet future navigation requirements. WES is helping develop new design and construction concepts for the Corps to reduce project costs. These concepts are quite different from previous lock designs used by the Corps, and laboratory experiments are necessary to help develop and evaluate these new innovative lock designs.

One recently completed research effort involved through-the-sill intakes for lock projects. Physical models were used to evaluate and improve flow conditions in the upper lock approach to obtain uniformly distributed flow and to eliminate strong vortices. In a model study for the Corps' Nashville District of a 366-meter-lock addition at the existing Kentucky Lock and Dam project, a through-the-sill intake was successfully developed.


*Model studies are helping develop and evaluate innovative cost-effective designs for navigation structures, such as Marmet Lock*

An in-chamber longitudinal culvert system was developed for the 366-meter-long McAlpine Lock addition. An in-chamber culvert system is much less expensive than a conventional culvert system with the culverts located inside the lock walls. The McAlpine design consisted of two culverts with ports centered around the midpoint of the lock chamber, which provides a well-balanced filling system with minimal surface disturbance. WES is developing design criteria for the in-chamber longitudinal culvert system.

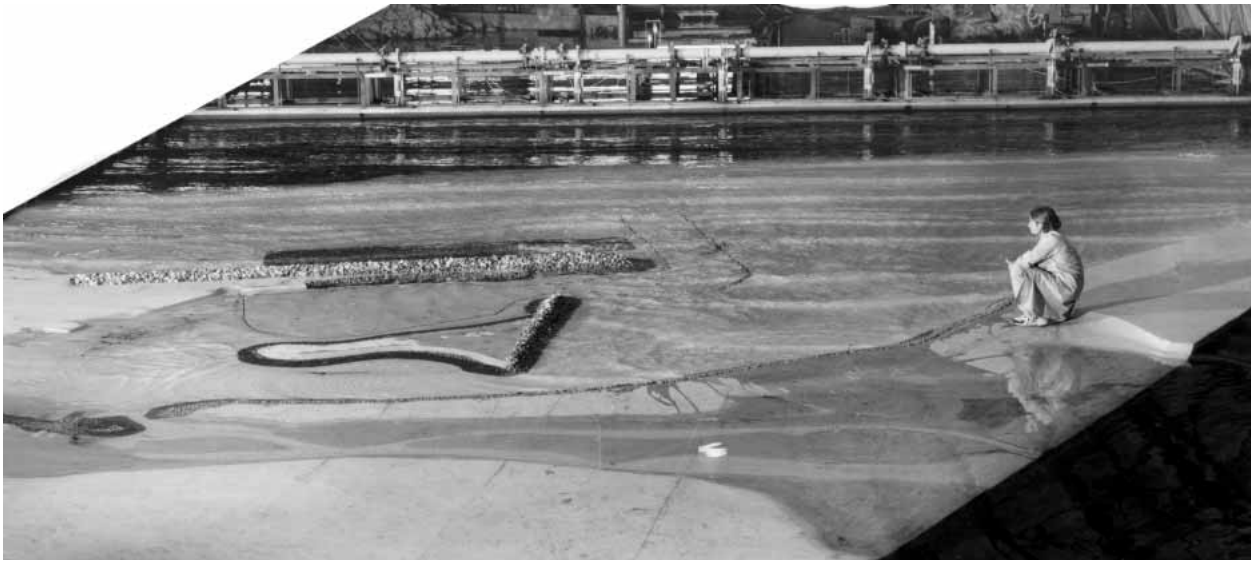
Other efforts include a laboratory investigation of the 244-meter-long Marmet replacement lock on the Kanawha River for the Corps' Huntington District. The in-chamber longitudinal culvert design is being evaluated with a through-the-sill intake and filling and emptying valves located in the lock walls.

WES is also developing design guidance for the most effective methods to rehabilitate and increase the size of an existing 183-meter-long lock to a 366-meter-lock. Analytical and laboratory investigations were also initiated to determine the flow conditions and hydraulic forces on the float-in segments during the different construction phases of the Monongahela No. 2 Navigation Dam replacement project.

**London Locks & Dam, Kanawha River.** London Locks & Dam is one of a series of Corps dams on the Kanawha River in West Virginia built in the 1930s. Studies are under way to examine proposed improvements to the locks and navigation channels on the Kanawha River system.

The 1:100-scale physical navigation model of London Locks & Dam was constructed to examine the proposed replacement of the upstream guard wall and a proposed dike in the lower pool to reduce crosscurrents in the lower lock approach. The model replicates about 4.1 kilometers of the project area. The model examinations are almost finished. Study results will help provide guidance for the design of the proposed upstream guard wall and the navigation effects of the proposed lower pool dike.

**Model Study of St. Paul Harbor, Alaska.** St. Paul Harbor is located on the southern tip of the largest island of the Pribilofs in the eastern Bering Sea. It is protected by a 550-meter-long main breakwater and a 300-meter-long detached structure. A harbor expansion that would include deepening the entrance channel, dredging a deeper and larger maneuvering basin, and constructing a wave-dissipating landfill in the harbor is being studied. Since the harbor also experiences overtopping of the main breakwater during storms, submerged reefs seaward of the breakwater are also proposed.



*St. Paul Harbor model*

A 1:100-scale model of St. Paul Harbor was constructed to determine the impacts of the proposed modifications on wave, current, sedimentation, and tidal flushing conditions. The model reproduces about 3,000 meters of the St. Paul Island shoreline, the existing harbor, and Bering Sea bathymetry to an offshore depth of 12 meters.

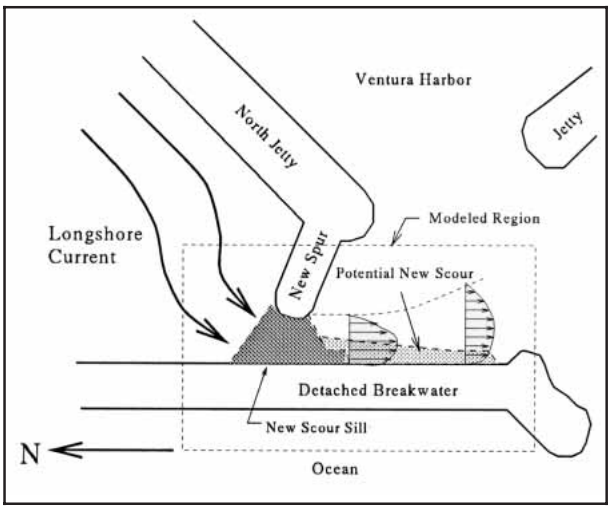
A spectral wave generator and crushed-coal tracer material were used in the model. Using the model, the locations and configurations of a wave-dissipating landfill and submerged reefs were optimized with regard to hydrodynamics and sedimentation. The model's optimum design will allow harbor expansions that will significantly reduce wave heights in the harbor.

The model was used to study both wave-induced circulation and tidal flushing of an adjacent salt lagoon connected to the harbor. Experiments were also conducted of a proposed small-boat harbor modification to determine wave conditions, current patterns and magnitudes, and sediment movement patterns and subsequent deposits within the complex. The model provided an optimum design that will result in adequate wave heights in the small-boat mooring areas while providing adequate circulation and flushing of the harbor and salt lagoon.

**Scour Protection for Ventura Harbor Detached Breakwater.** In 1995 a significant scour hole developed at the Ventura Harbor entrance channel due to accelerated strong longshore currents in a narrow gap between the detached breakwater and the end of a recently constructed jetty spur on the north breakwater. The Corps' Los Angeles District performed an emergency repair, but additional scour continued to occur downstream of the repaired section, which would damage the lee side armor slope of the detached breakwater and result in expensive repairs.

A joint Los Angeles District-WES study was initiated. A laboratory movable-bed model of the scour region was built to determine the probable extent of scour and to test and refine the District's 1996 scour protection design. The completed joint study produced results that will have major benefits for the project.

The model study confirmed that scour would undermine the detached breakwater toe and that the proposed toe reinforcement would need to extend over the entire downstream length of the detached breakwater. The physical model helped optimize the toe apron cross-section design and demonstrated the design was stable with sufficient residual protection. The final design used 25 percent less stone than the 1996 design and prevented an estimated $475,000 in additional breakwater damage that might have occurred in the absence of adequate toe scour protection.




*Ventura Harbor scour problem*

**Monitoring Completed Navigation Projects (MCNP) — Barnegat Inlet, N. J.** Barnegat, one of the most dangerous inlets on the East Coast, was modified with a new 1,220-meter-long rock south jetty in 1992. In 1968, the very existence of the inlet was in jeopardy as the channel cross section was diminishing due to high sand influx rates. Initially the north jetty crest was raised and made impermeable to sand transport; the new south jetty completed the project. This jetty converted the system from an arrowhead orientation to parallel jetties, which straightened and deepened the channel and potentially improved navigation through the inlet. To evaluate the effectiveness of these

inlet improvements, a five-year monitoring program was initiated in 1993 as part of the MCNP research program.

Monitoring of Barnegat was performed in partnership with the Corps' Philadelphia District. The study has shown that inlet channel location is a complex function of inlet hydraulics, littoral influx to the channel system, and inlet structures. With the original arrowhead jetty system, sedimentation reduced channel cross-sectional area with a corresponding reduction in tidal prism. Today's inlet, which is still adjusting to the new parallel south jetty, appears to allow a more stable and safer channel to exist due to the restriction of sediment input into the navigation channel. These factors, along with an increase in minimum channel area due to dredging, have restored the tidal prism back to the natural pre-structures conditions.

*Collecting a sediment sample at Barnegat Inlet*